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NASA TECHNICAL TRANSLATION

NASA TT- 20079

P-32

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Translation of "Interaction d'un mat support de maquette sur les mesures des coefficients aerodynamiques longitudinaux" Association aeronautique et astronautique de France, Colloque d'aerodynamique Appliquee,23rd, Aussois, France, Nov 12-14, 1986, TP, No. 1986-181, 28 pp.
A87-21080

(NASA-TT-20079) THE INTERFERENCE OF THE MODEL SUPPORT MAST WITH MEASUREMENTS OF THE LONGITUDINAL AND LATERAL AERODYNAMIC COEFFICIENTS (NASA) 32 p Avail: NTIS HC A03/MF A01 CSCL 01A G5/02

N87-25307

Unclas
0085576

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D.C. 20546
AUGUST 1987

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TT-20079		

4. Title and Subtitle	5. Report Date
THE INTERFERENCE OF THE MODEL SUPPORT MAST WITH MEASUREMENTS OF THE LONGITUDINAL AND LATERAL AERODYNAMIC COEFFICIENTS.	August 1987
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
C. van de Kreeke, J. Verriere, G. Quemard	
	10. Work Unit No.

9. Performing Organization Name and Address	11. Contract or Grant No.
Leo Kanner Associates Redwood City, CA 94063	NASw-4005
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	
National Aeronautics and Space Administration Washington D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Interaction d'un mat support de maquette sur les mesures des coefficients aerodynamiques longitudinaux et lateraux, Association aeronautique et Astronautique de France, Colloque d'Aerodynamique Appliquee, 23rd, Aussois, France, Nov 12-14, 1986, ONERA, TP, No. 1986-181, 1986, 28 pp. A87-21080

16. Abstract

The effects of single bottom support masts used in ONERA S1 and S4 wind tunnels were examined experimentally and analytically on the basis of aerodynamic data collected with scale model aircraft. Systematic studies were conducted on the flow characteristics around different diameters for the mounts. Scaling methods used to make data from one wind tunnel corcorresond to data from the other. Airbus 320 models were introduced into tests and mast-body flow interferences were observed. A summary is presented of restrictions on the mast diamters, relative to cylindrical model diameters, which will minimize the effects the masts have on longitudinal and lateral aerodynamic stability data.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified-Unlimited

19. Security Classif.(of this report)	20. Security Classif. (of this page)	21. No. of pages	22.
Unclassified	Unclassified		

THE INTERFERENCE OF THE MODEL SUPPORT MAST WITH MEASUREMENTS OF THE LONGITUDINAL AND LATERAL AERODYNAMIC COEFFICIENTS

C. van de Kreeke, J. Verriere, G. Quemard

SUMMARY

The lateral stability tests of civilian aircraft models are carried out in ONERA's F1 wind tunnel and CEAT's S4 wind tunnel on a single mast type rig: the model is fastened by means of a balance with a vertical mast incorporated with devices for creating an angle of attack and and side-slip.

During tests on ATR42 models performed in two wind tunnels, major discrepancies were observed on the lateral stability results. With the support of the official services, AEROSPATIALE and ONERA undertook systematic studies in F1 and S4 to try to understand the origin of these discrepancies. We were able to show that the very apparent interference of a mast with the undercarriage fairing of ATR42 played an essential role, as the effect was proportional to the relative mast size, that is larger at F1 than at S4.

Since AIRBUS A430 also has an apparent undercarriage fairing, AEROSPATIALE and ONERA defined a second series of experiments for quantifying the interference of a single mast for future testing of models of this aircraft in the F1 wind tunnel, but also in the S1 wind tunnel of the Modane Center: in S1 the ground effects are actually studied by comparing the model of the wind tunnel floor using a telescoping mast.

An A320 model was installed in CEAT's S4 wind tunnel on a "3 mast" support and the aerodynamic stresses were measured whether or not in the presence of a single mast dummy placed between the model and a reference floor. By varying the distance between the floor and the model we were able to show that the ground effect is

not greatly affected by the presence of the mast. The measurements also provided orders of magnitude of the corrections to be made to the absolute values of the lift and pitch momenta coefficients.

INTRODUCTION /1*

Aerodynamic coefficients can be accurately determined only after correcting the disturbing effects due to the presence of the model support.

The first effects leads to "wall" correction which are currently well defined for a subsonic flow. The order of magnitude of the corrections required by the presence of supports thus has become greater than that of the wall correction uncertainties.

The search for absoslute values of aerodynamic coefficients (civilian aircraft in particular) based on wind tunnel measurements coupled with the fear that the support effects doe not mask the effect of the Reynolds number, an essential parameter of pressurized wind tunnels, therefore logically led to a systematic study of the disturbances created by the different supports uded in a wind tunnel: "single mast", "three masts", stings.

The latter two mounting types are primarily used for longitudinal performance and stability studies and are currently studied as part of a GARTEUR group.

The "single mast" mounting is used in ONERA's F1 Center at Fauga-Mauzac and the ONERA's S1 wind tunnel at Modane for testing ground effects. Comparisons between the results obtained in the S4 and F1 wind tunnels on ATR42 models showed major discrepancies in the roll moment coefficients and were the source of the study presented herewith.

1 - DESCRIPTION OF THE PROBLEM /2

The photographs of figures 1 and 2 show models of the ATR42 regional transport aircraft on a 1/15 scale in CEAT'ss S4 atmospheric wind tunnel, and on a 1/8 scale in CFM's F1 pressurized wind tunnel.

*Numbers in the margin indicate pagination in the original text.

In the two cases, the models were fastened via a balance inside a mast recovered on an angle of attack initiation sector (figure 3), located under the floor of the test section at F1, under the free jet at S4. The essential difference between the S4 and F1 mountings is that at F1, the rotation in azimuth is the vertical axis and is done "before" the angle of attack rotation, whereas at S4 it is done about the mast axis, "after" the model has been tilted.

Figures 1 and 2 show that the mast used at F1 is relatively larger than that of S4. The diameter ∅ ratios of the mast/ diameter of the fuselage are equal to 0.17 at S4, 0.34 at F1.

The first lateral stability measurements, characterized by the derivative of the roll moment coefficient Cn according to the side-slip angle β hereafter), performed at F1 and following a campaign at S4, surprised the authorities at Aerospatiale: figure 4 shows discrepancies of up to 80% between the results of the two wind tunnels.

This is when it was decided to conduct the first experiments to define the problem of the mast's interference on the flow around the model.

This interference could be calculated as a difference between the aerodynamic coefficients resulting from a calculation of the flow around the model with and without the mast.

Computer programs using the singularities distributions method on the surface of equipment obstacles are operational but obviously on the assumption of a perfect fluid flow, without viscosities. Figure 5, on the other hand, shows the magnitude of the viscous interference on the behavior of the flow near the mast and fuselage connection. A system of horseshoe vortices issuing from the mast base interferes with the particular flow which forms around the ATR42 undercarriage fairings.

Oriented by the local appearance of this interference and thanks to STPA's support, an experimental program was established in CEAT's S4 wind tunnel in order to:

-search for a local remedy to the mast's interference,
-characterized the impact of the realtive mast diameter.

2 - IMPACT OF A SUPPORT MAST ON ATR42's THE LATERAL STABILITY MEASUREMENT /3

Various changes in the mast-fuselage connection, which need not be described in detail, were proposed by Aerospatiale and ONERA in an attempt to reduce or eliminate the vortex interferen- ces and their effects on the derivative Cnβ.

Figure 6 shows for example the impact of a sort of "vortex trap" which surrounds the base of a mast reproducing the mast of F1 on S4's scale. The roll moment coefficient Cn is reduced in to an absolute value and the Cnβ derivative becomes close to the derivative obtained with the thinner mast of S4. Figure 7 shows the relatively large success in the various modifications proposed. The main conclusion is that it is possible, via a very local modification of the geometry at the connection level with the fuselage, to very substantially reduce the mast interference.

The simplest modification, at least in principle, indeed remains to reduce the relative size of the mast, since the zero interference is caused by a mast that has a diameter of zero.

A systematic study of the impact of the relative diameter, divided between two S4 test campaigns therefore completed the first experiments.

Coverings of various diameters made it possible to reproduce the F1 mast on an S4 scale and a mast with a diameter between that of S4 and F1, the mast Ø/fuselage Ø ratio varying between 0.17 to 0.34, with an intermediate ratio 0.22 corresponding to an

80 mm Ø diameter at F1.

Figure 8 shows the variation of Cnβ measured at S4 at a zero angle of attack in configurations of raised flaps turned by 40°C. Indeed we find in these experiments virtually twice the Cnβ values between measurements with an S4 type mast and F1 type mast. The results on the 3 Masts are discussed below.

The discrepancies between the Cnβ measured at F1 and S4 are virtually independent from the flap deflection, i.e. the configuration. When the angle of attack increases, these discrepancies decrease while remaining within a first approximation independent of the configuration (figure 9).

One question remains to be raised however: how to extrapolate the preceding results for an infinitely thin mast, Ø -> ? To try to solve this problem, a special test was conducted at F1 on a "three mast" mount shown in figure 10.

The usual mount has a downstream mast of relative thickness and chord similar to those of upstream masts, and partially removed from the wind effects by a fairing. To prevent large corrections of the roll moment due to the lift of this mast when the mounting system is set into a side-slip motion, this downstream mast was replaced by a 20 Ø mm rod. After setting this entire new supporte without model, testing at zero angle of attack in flap configurations at 0 and 40° provided the Cn (β) measurement over a range of $-5 < \beta < +5°$. The results are shown in figure 8 by arrows: they cross-check the results obtained at S4 on the thin S4 mat (mat Ø / fuselage Ø = 0.17).

The extrapolation of the results obtained with a mast that has a relative diameter of 0.17 does not seem necessary. This relative diameter seems to be suitable for side-slip testing.

3 - LATERAL STABILITY OF THE A310 AND A320 MODELS /4

Now that the case of the ATR42 models has been described, Aerospatiale and ONERA naturally wondered whether the lateral stability tests conducted some time before F1 on an A310 model had been influenced by the mast interference.

An A300B model on a 3/100th scale was mounted on the mst of wind tunnel S4 and, as with ATR42, we used fittings to vary the size of this mast. Figure 11 shows that the Cn β measurements are much less dependent on the mast size than in the case of ATR42. This conclusion, given here for the cruise configuration, is also valid in the approach configuration.

The essential differences between the two ATR42 and A300B masts, in regard to mast interference, are the wing position on the one hand, lower on A300, and that the ATR442 undercarriages are very apparent undercarriages on ATR442, but inexistent on A300.

This observation is itself a new confirmation that the mast interference is highly influenced by the local geometry of the mast-fuselage connection: small interference when the fuselage is cylindrical, large when the fuselage shape is altered by the outgrowth of the undercarriage fairing.

Consequently, the question is raised of future tests on AS20 which have an apparent undercarriage fairing, although clearly much less distinct than that of ATR42, as shown in the diagrams of figure 13.

The A300B model was then modified to reproduce the main forms of an A320 (lowered wing, addition of an undercarriage fairing) and tests were conducted in the S4 windtunnel of CEAT to:

assess the extent of the mast effects;

-justify the production of a new mast for F1, since a smaller diameter (80 mm ∅) could be accepted to hold the structure for an A320 model.

These tests, using the same type of mount as for ATR42 and A300B, led to the results shown in figure 14. We see that for a mast equivalent to a mast with diameter of 80 mm ∅ at F1 the discrepancies with the measurements performed on the S4 thin mast are 5% at the most. This result was deemed to be correct by Aerospatiale and the decision was then made by ONERA to make a new mast: figure 15 represents the A320 on a 1/11 scale mounted last August at F1 on an 80 mm ∅ mast.

It was also planned to study the impact of the mast in the F1 wind tunnel by conducting a weighing test of the model held by the upper surface with and without a mast dummy.

Since the presence of an upper surface support mast was likely to distort the comparison, a test was conducted at S4 of successive weighings of the model on lower surface masts of different diameters, in the presence of an upper surface mat dummy (Figure 16).

Figure 17 shows that the Cn β variations with the undersurface /5

mast size are not influenced by the presence of an upper surface mast: the latter therefore does not disturb the effect of the lower surface mast, at least within the diameter range of 0.19 to 0.25.

It would therefore be possible to determine at F1 the effect of the mast by the upper surface weighing and dummy method.

4 - IMPACT OF MATS ON THE LONGITUDINAL COEFFICIENTS OF A320

Now that the mast effect on the lateral characteristics of A320 has been defined, the problem of their effect on the

longitudinal coefficients was still raised, although with less anxiety because the study of the longitudinal behavior of civilian aircraft is primarily carried out on three masts. This excludes, however, the special case of the study of the ground effect which is carried out in the S1 wind tunnel of Modane using a telescopic mast. The question then becomes, does the support mast influence the ground effect?

Figure 18 shows the mount used at S4 to provide an answer. The A320 model was mounted on three masts, at a fixed altitude in the test section. A mobile floor was moved closer to the model to simulate the approaching ground. For various angles of attack and various configurations, the aerodynamic stress measurements were performed with and without a mast dummy representing the telescopic mast of S1 on the S4 scale. By differentiation we obtain the effect of the mast at various heights of the model from the ground.

Within the measuring accuracy limits, the mastt effect was found to be independent of the distance to the ground. Figure 19 shows for example that an increase in the lift delta Cz created by the mast is constant, to the nearest + or -, for any delta Cm of the pitch moment coefficient.

These measurements at S4 are used to estimate the corrections to be made in the Cz and Cm coefficients for a mast with a given diameter and without ground effect (figure 20). The too imprecise delta Cx measurements were not processed. Figure 21 illustrates that F1's new 80 Ø mm mast indeed leads to delta Cm corrections of the pitch moment of close to 0.01, by comparing the tests performed on a single mast and on three masts for test points reported at iso-incidences. These corrections were equal to 0.04 for the A310 tests on the 120 mm Ø mast.

CONCLUSION /6

The first comparison of the results of ATR42 tests carried out

in CEAT's S4 wind tunnel and in ONERA's F1 wind tunnel showed that the support mast of the model, used in both wind tunnes to study the lateral stability, had at F1 a major interference on the lateral aerodynamic coefficients.

The experimental study conducted jointly by Aerospatiale, CEAT and ONERA with the support of STPA showed that:

-the interference is great only when the fuselage has a very apparent undercarriage fairing (case of the ATR42), the flow issuing from the mast then strongly interfers with the flow around the undercarriage fairing;

-in the case of cylindrically-shaped fuselages (case of A300, of A310) or those altered by a discrete undercarriage fairing (case of A320), a relative mast diameter (mast $\emptyset$ /fuselage $\emptyset$) of the order of 0.2 makes it possible to reduce the mast effects on the Cn β derivative to less than 5%. Such a mast was made for testing the A320 at F1.

This study also demonstrated the complementarity of large industrial wind tunnels, such as F1, and more modest wind tunnels, but more flexible to use, such as S4 and the necessity of constantly trying to validate wind tunnel tests by an ongoing comparison with the results from other wind tunnels.

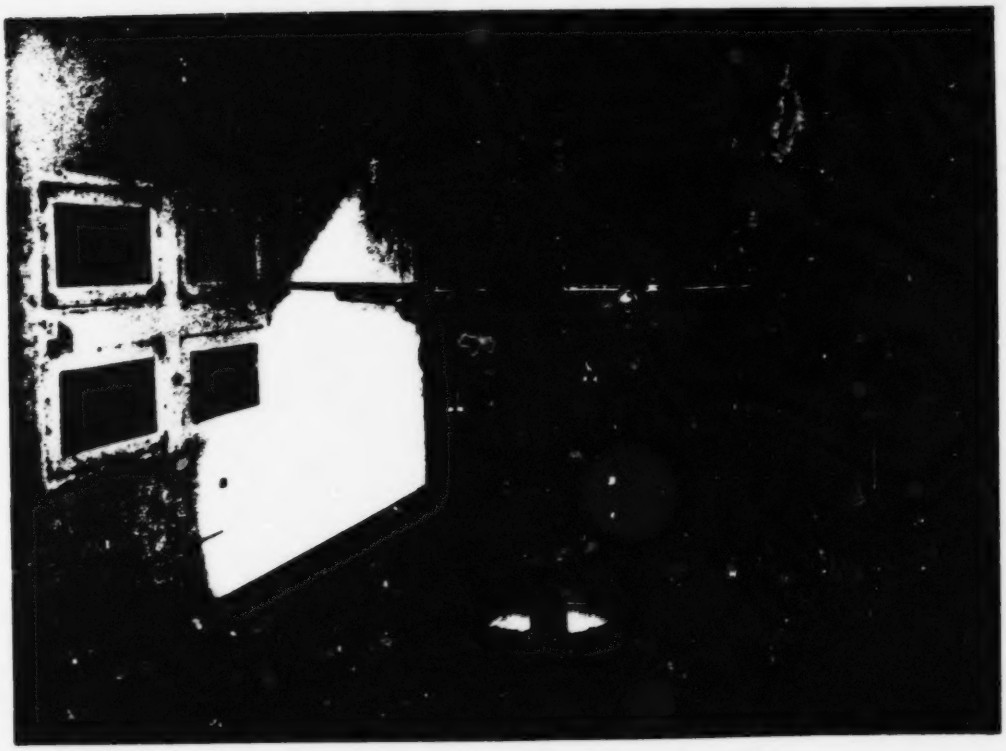

Figure 1: ATR 42 on 1/8 Scale in F1 Wind Tunnel

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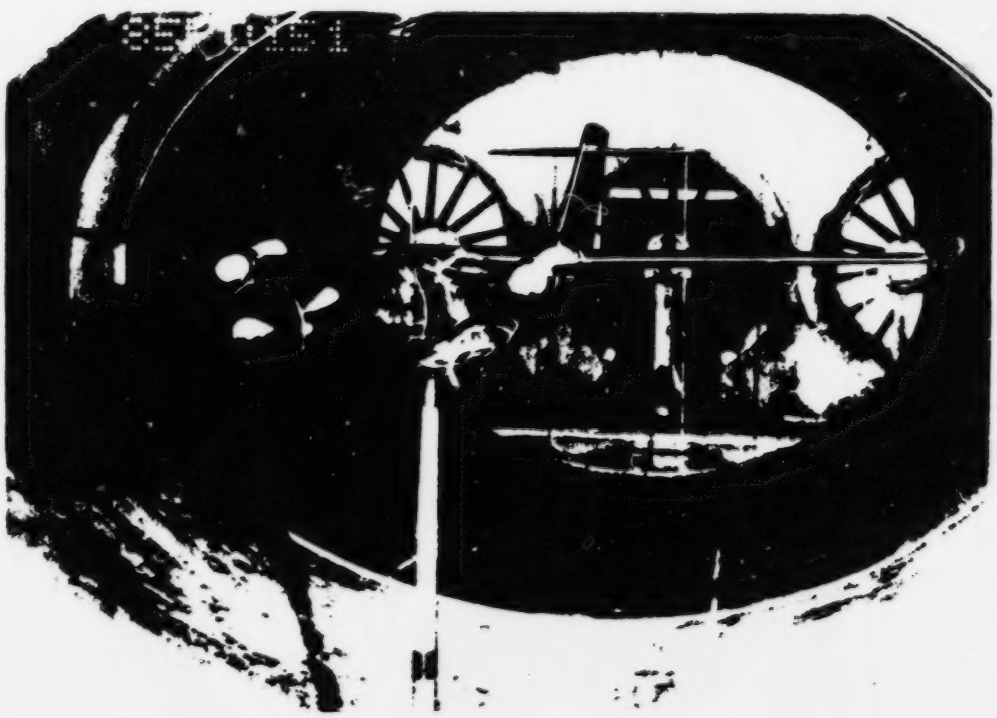

Figure 2: ATR 42 on a 1/15 Scale in the S4 Wind Tunnel

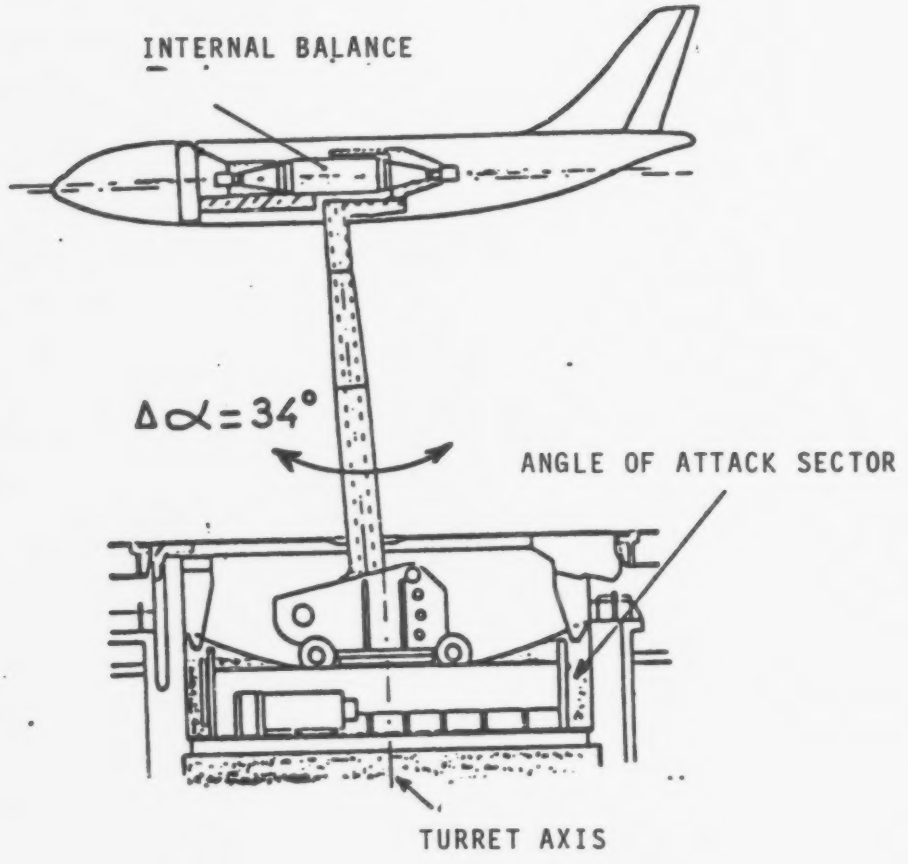

Figure 3: SINGLE MAST MOUNT AT F1

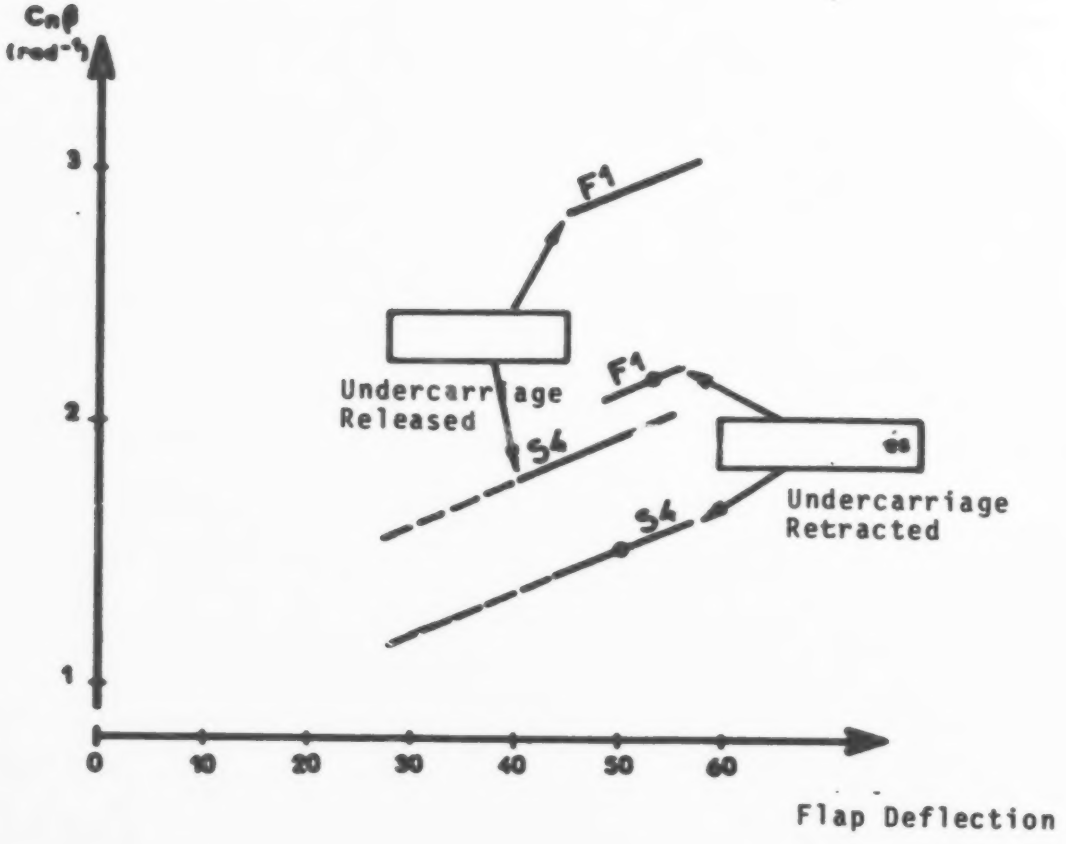

Figure 4 - ATR 42 - LATERAL STABILITY RESULTS AT F1 and S4

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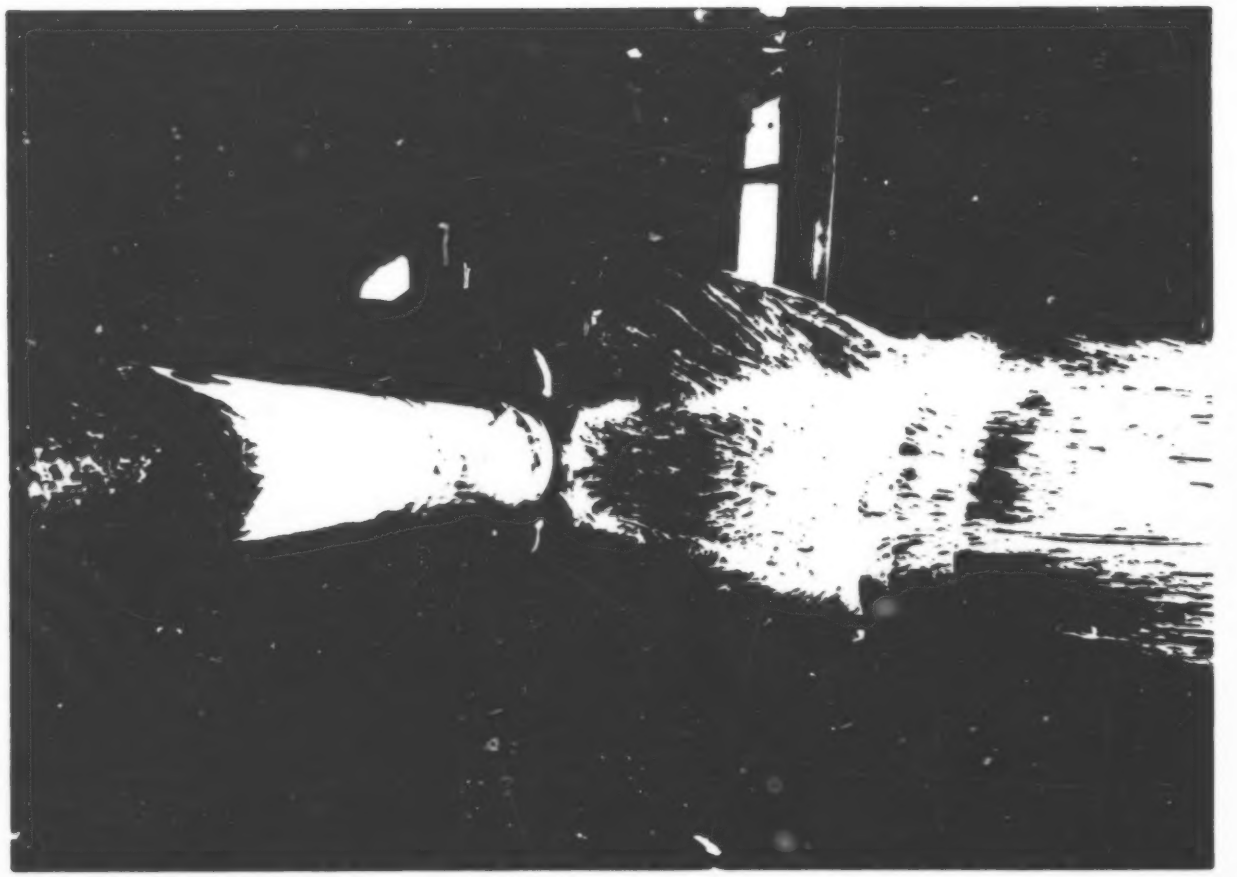

[visualisation F1]

Figure 5: View From Below of Mast-Fuselage Connection

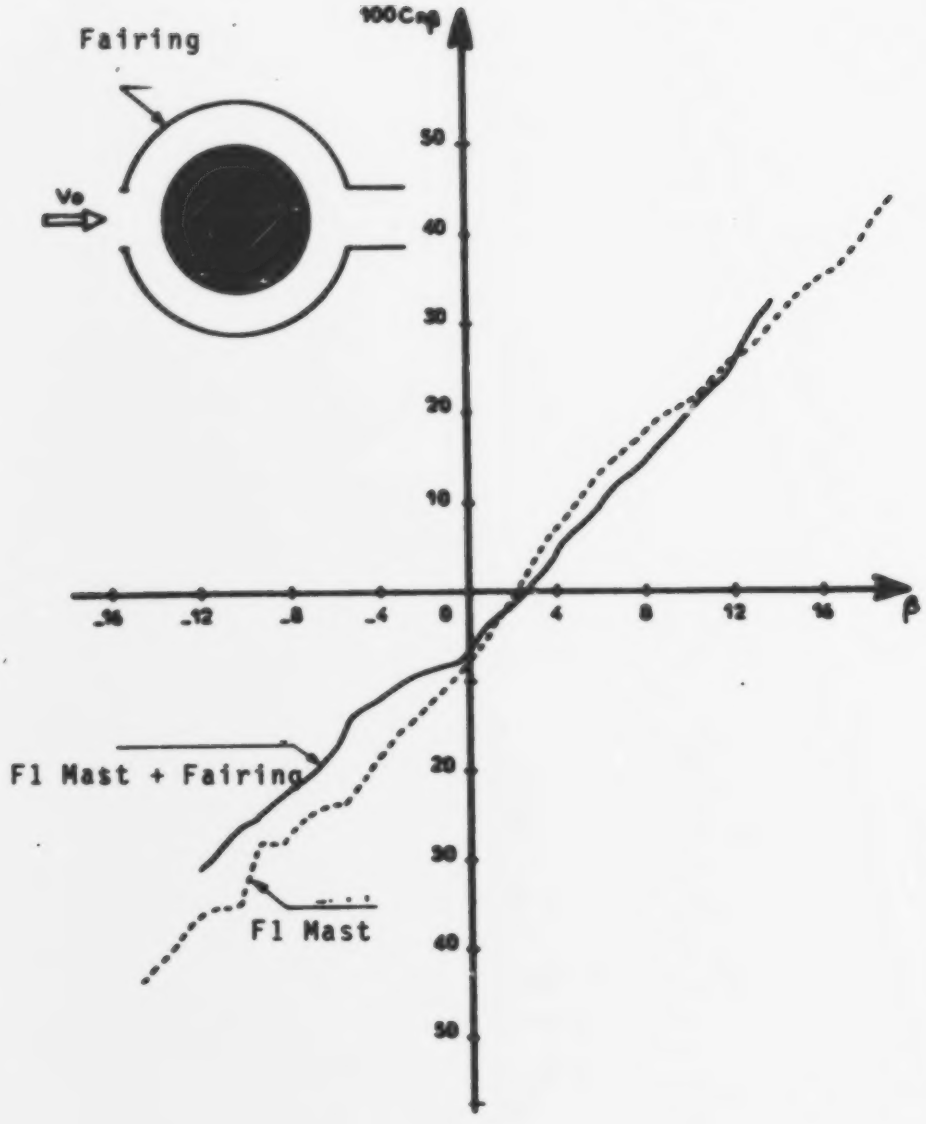

Figure 6: IMPACT OF A CHANGE IN GEOMETRY OF THE MAST-FUSELAGE CONNECTION

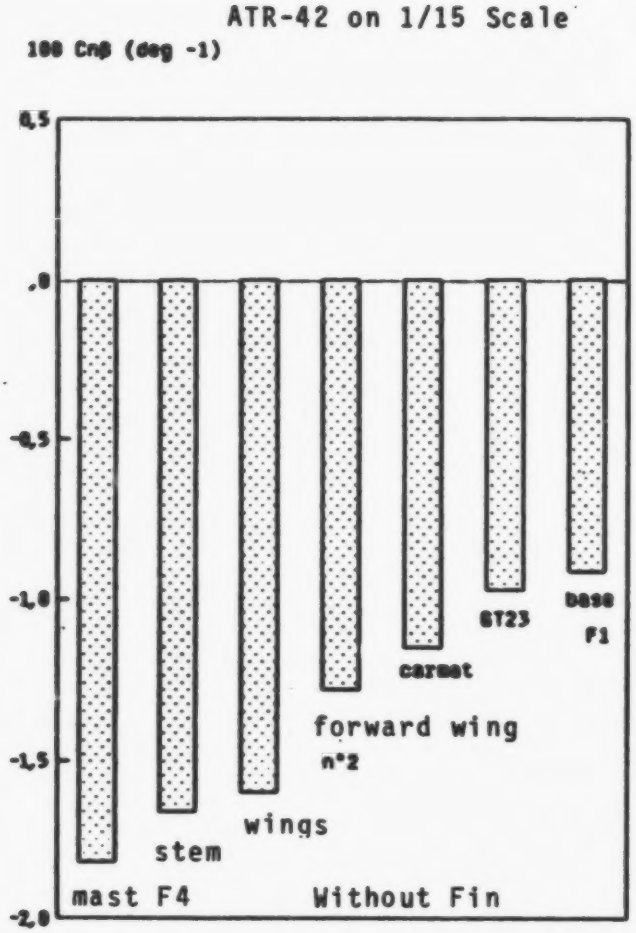

Figure 7 - IMPACT OF VARIOUS MODIFICATIONS OF MAT F1

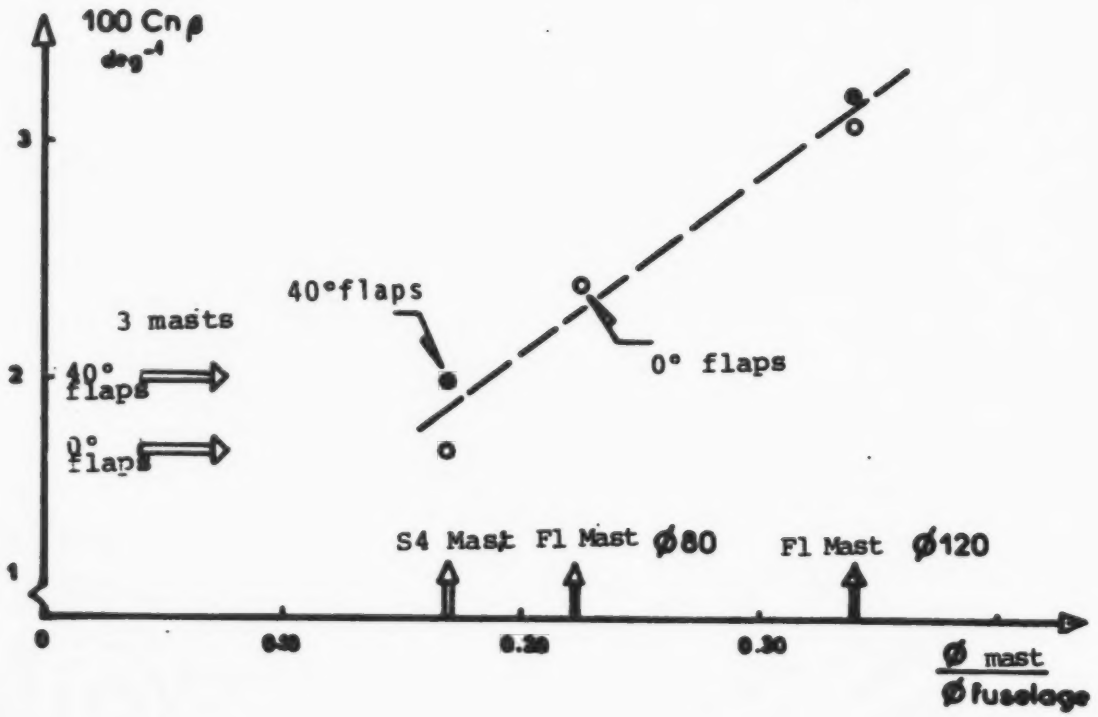

Figure 8 - ATR 42 EFFECT OF MAST SIZE ON CN β

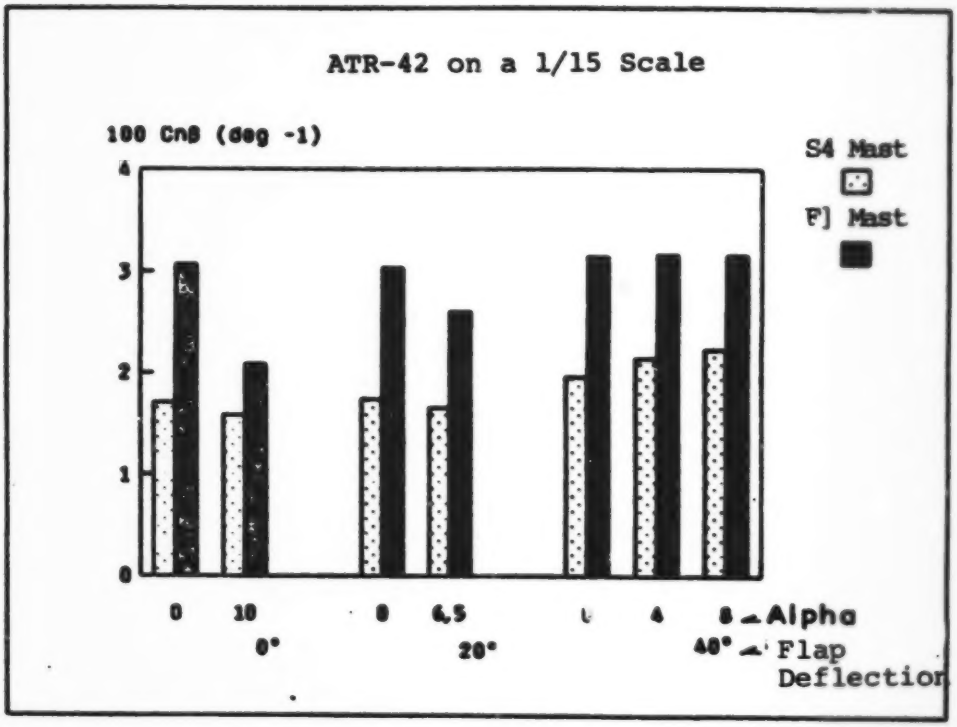

Figure 9 - VARIATIONS OF THE MAST EFFECT WITH ANGLE OF ATTACK FOR VARIOUS FLAP DEFLECTIONS

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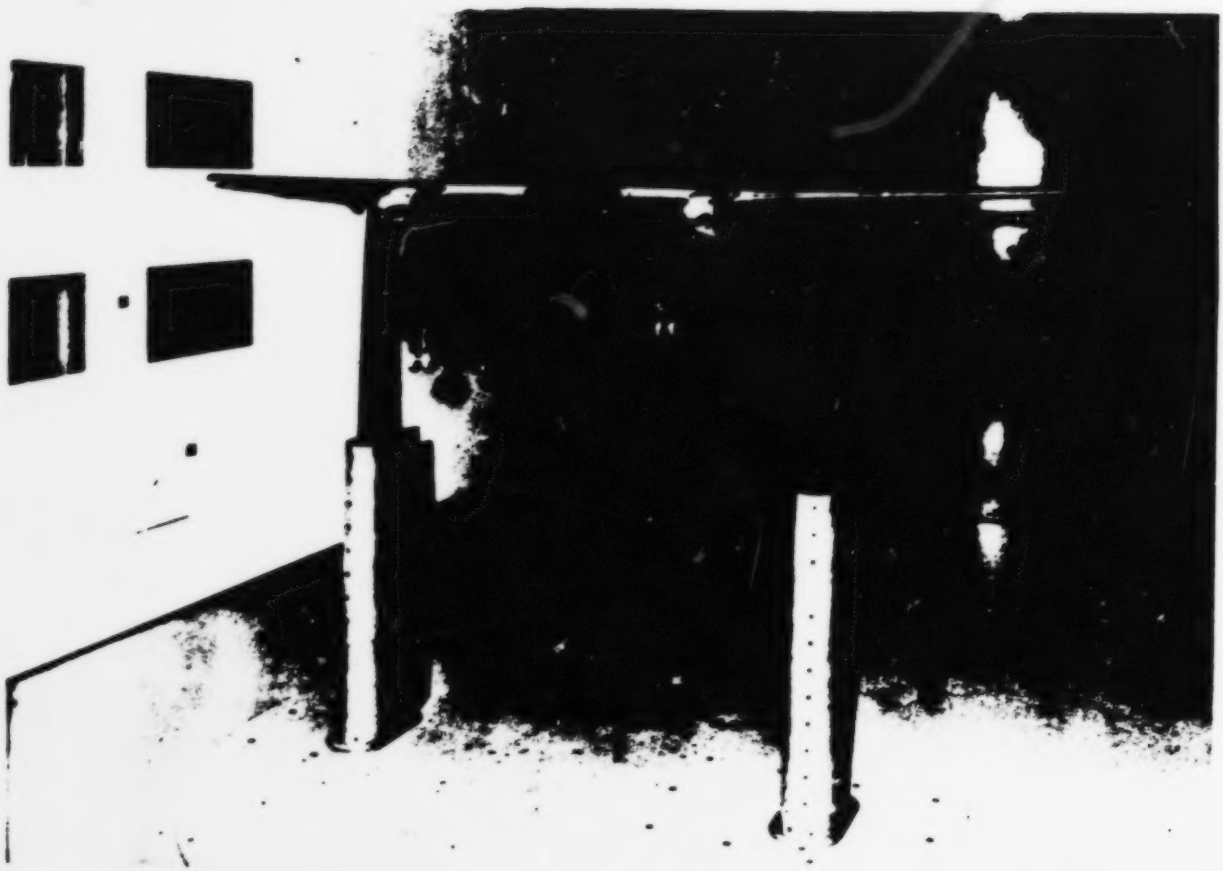

Figure 10 - MOUNT AT F1 of ATR 42 ON A "3 MAST" MINIMUM

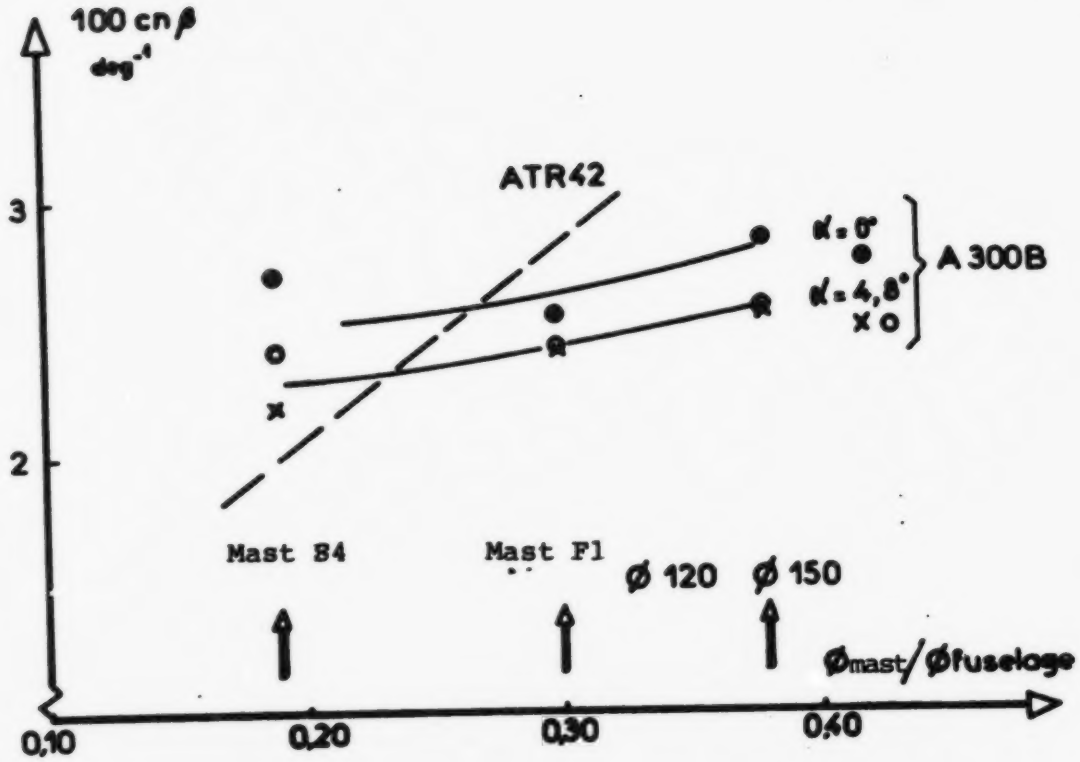

Figure 11 - EFFECT OF MAST SIZE ON Cn β OF A300 B (CRUISE)

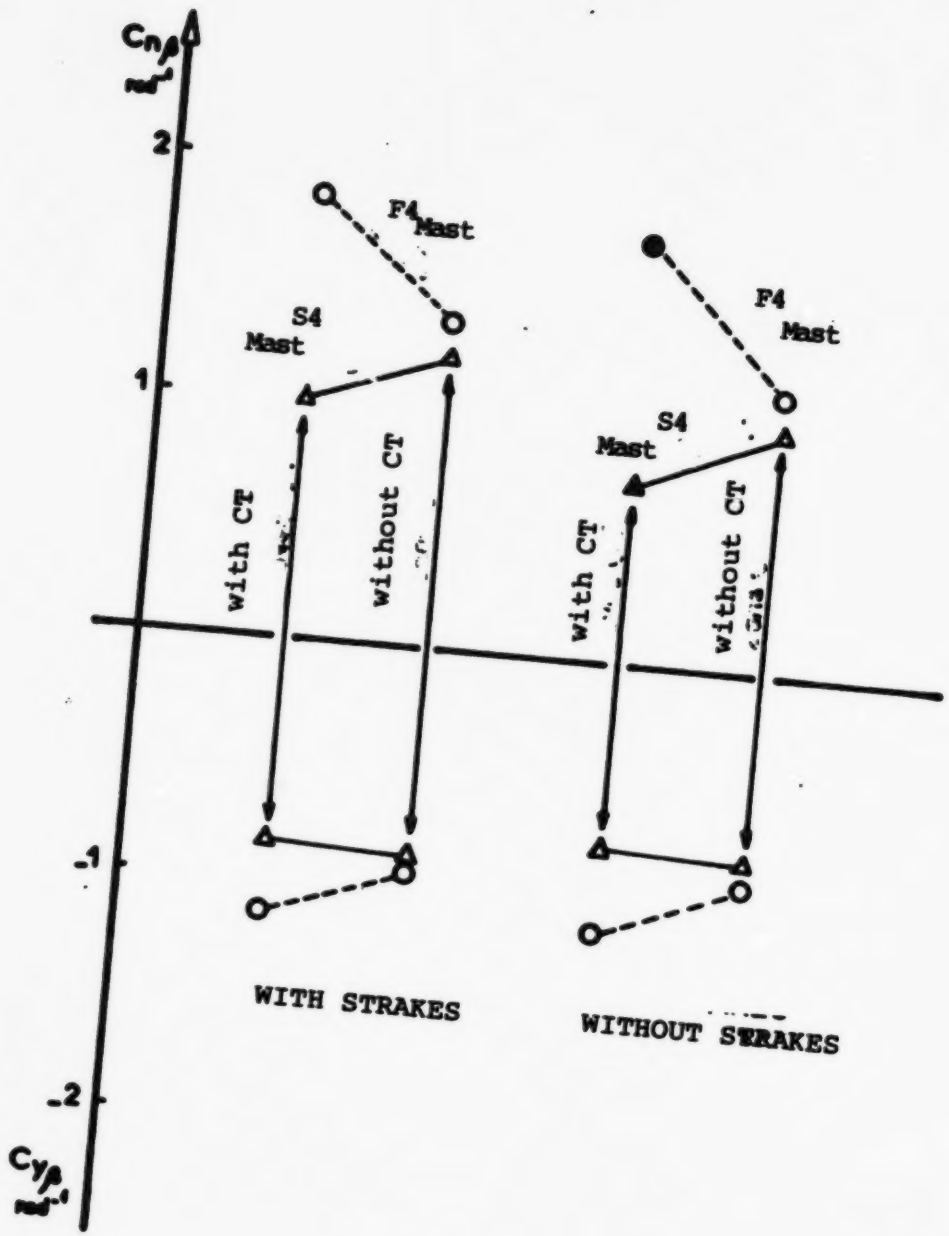

Figure 12 - ATR 42 IMPACT OF UNDERCARRIAGE FAIRING ON Cnβ (α=0°, flaps in)

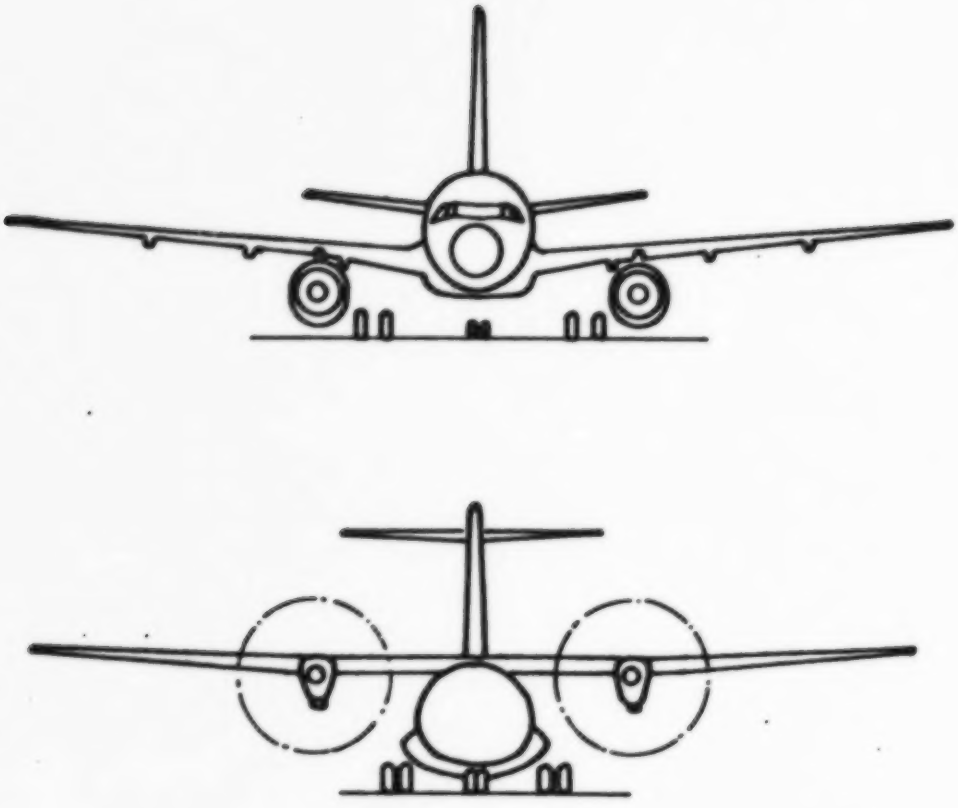

Figure 13 - VIEWS OF ATR42 AND A320 FACE

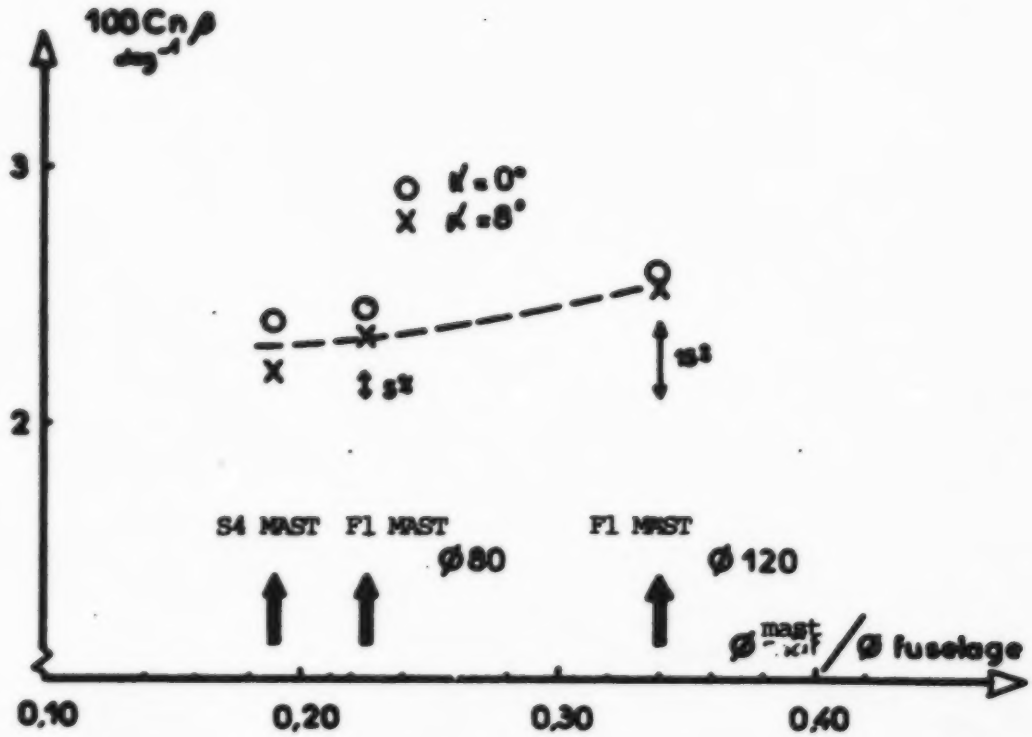

Figure 14 - A320 IMPACT OF MAST SIZE

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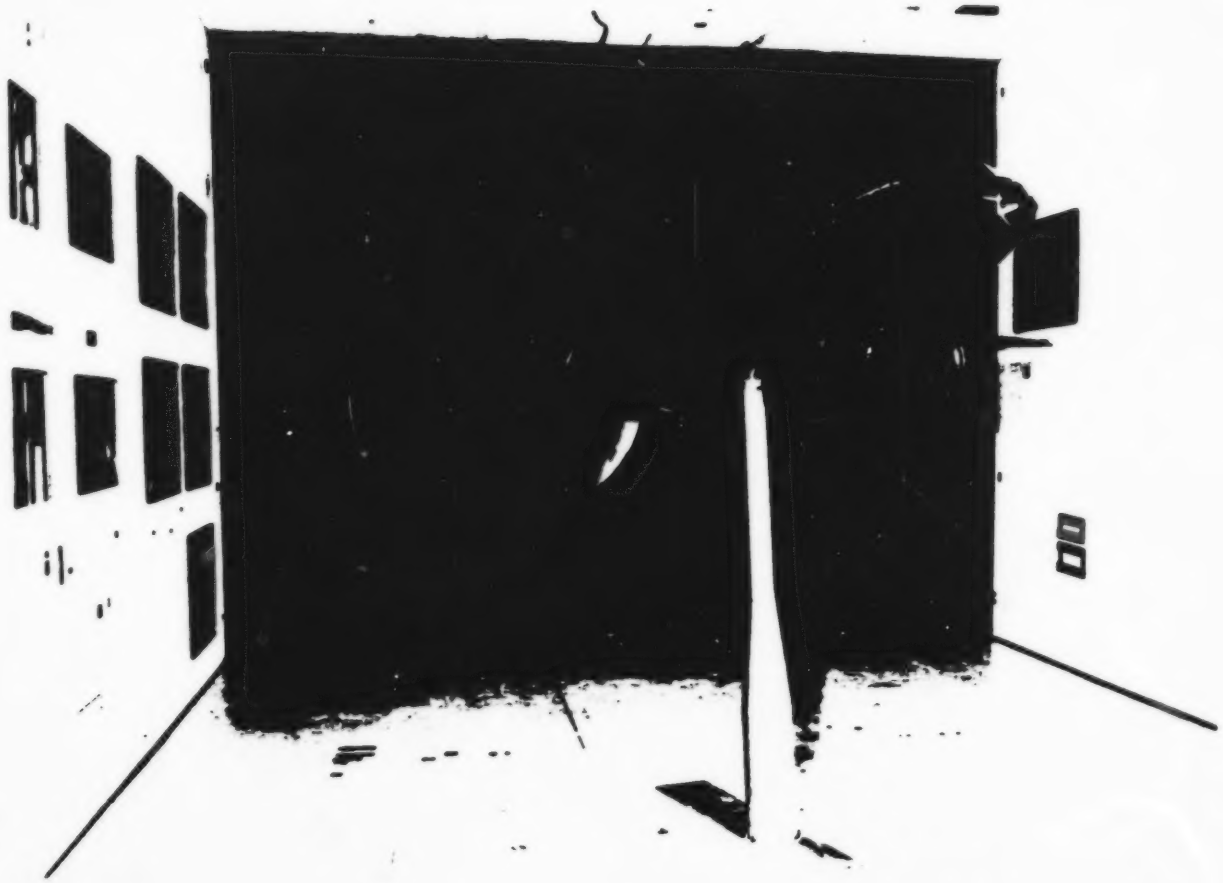

Figure 15 - MOUNT AT F1 of A320 at 11th.

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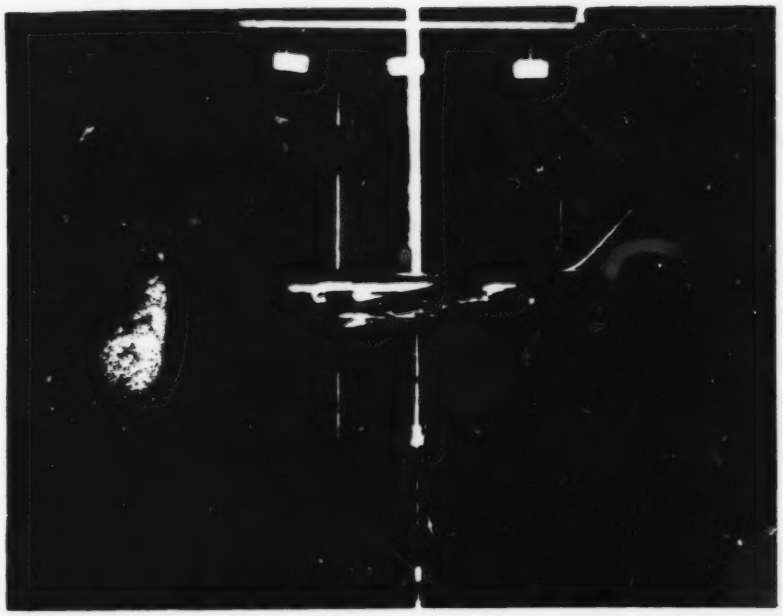

Figure 16 - MOUNT AT S4 OF A320 WITH IMAGE MAST

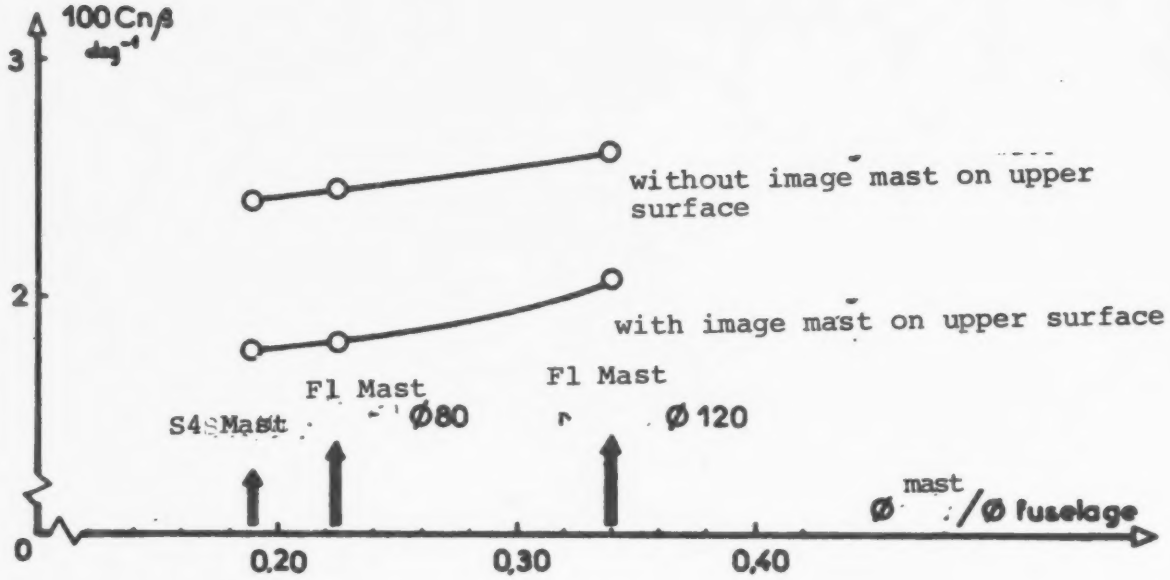

Figure 17 - VARIATIONS OF Cn β WITH MAST DIAMETER, WITH AND WIHTOUT FALSE UPPER SURFACE MASTS

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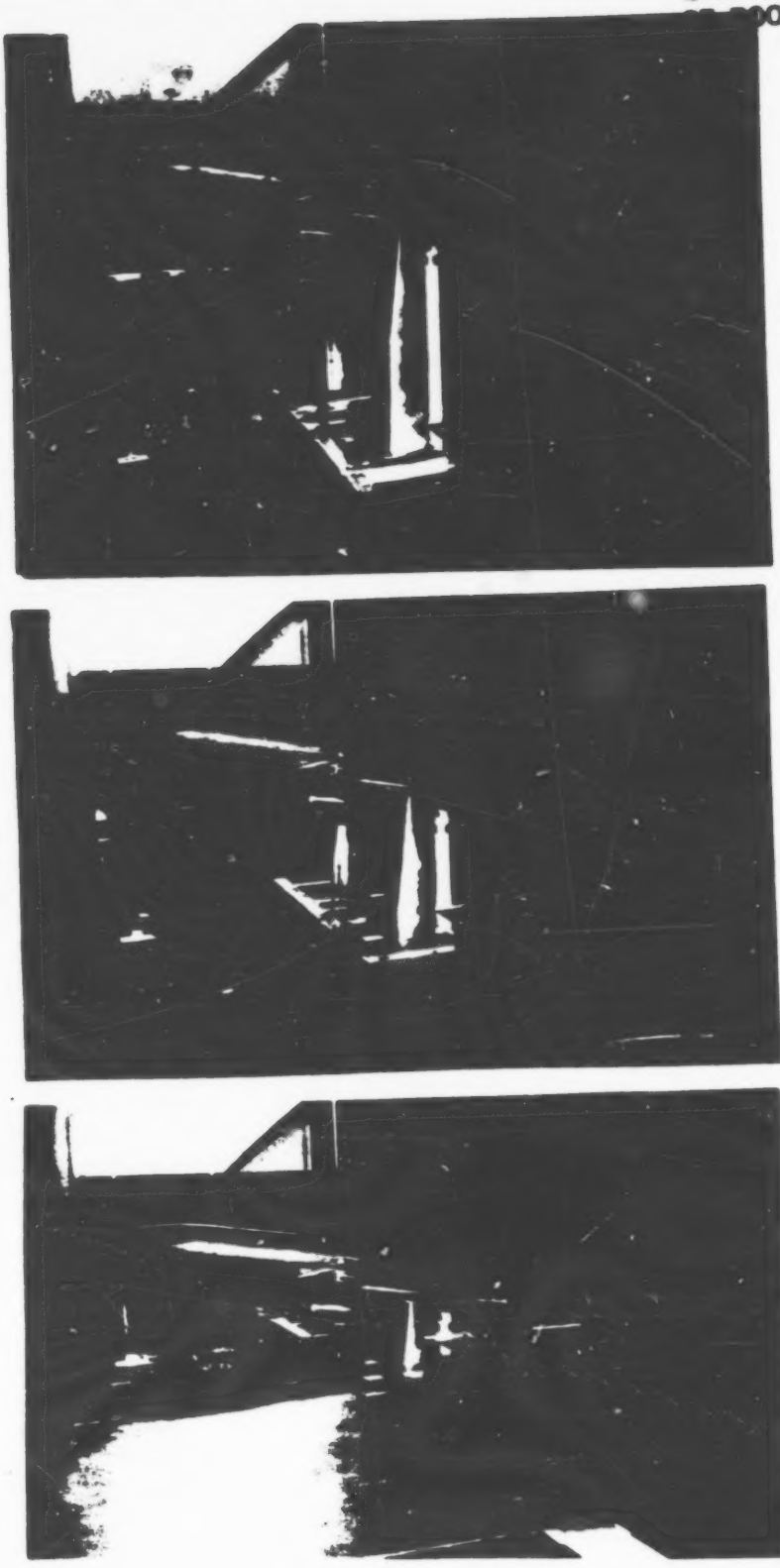


Figure 18 - STUDY OF MAST EFFECT IN PRESENCE OF GROUND

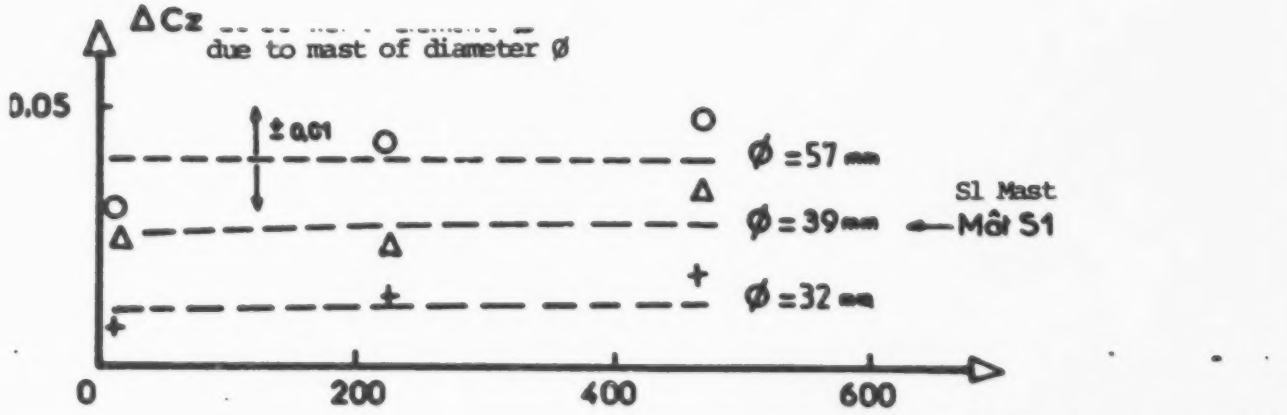


Figure 19 - A 320 IMPACT OF MAST SIZE FOR DIFFERENT DISTANCE FROM GROUND (TAKEOFF)

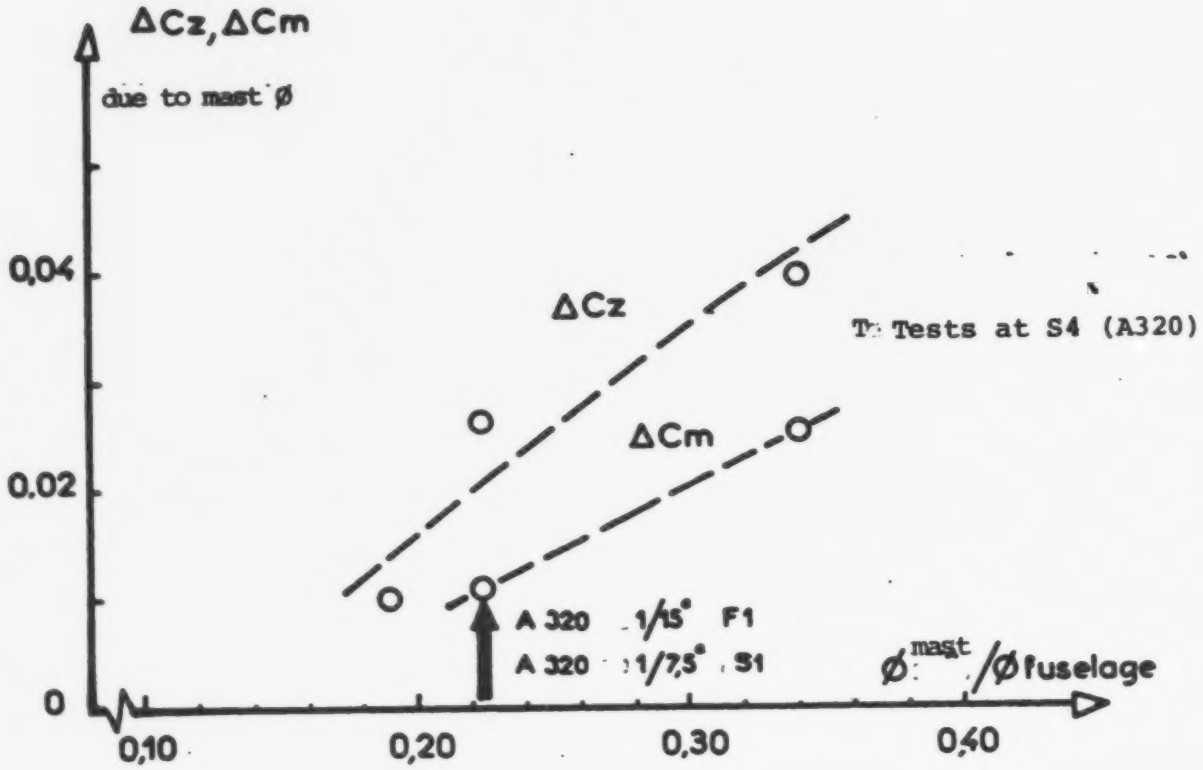
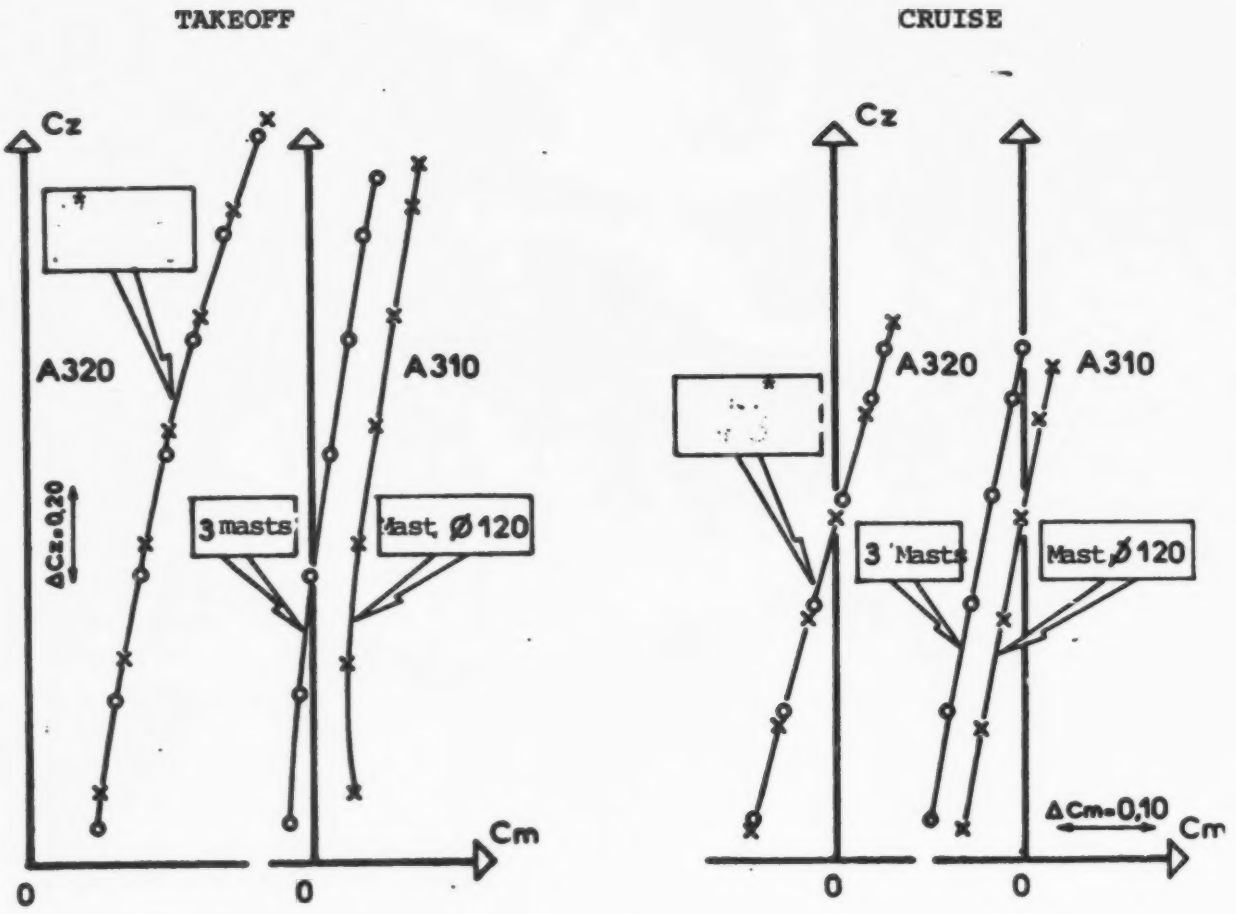


Figure 20 - IMPACT OF MAST ON LIFT COEFFICIENT



*3 Masts and Ø80 Mast

Figure 21 - COMPARISON OF Cm OBTAINED ON 3 MASTS AND SINGLE MAST Ø 80 AND 120